Glass and Ceramics, Vol. 70, Nos. 7 – 8, November, 2013 (Russian Original, Nos. 7 – 8, July – August, 2013)

UDC 666.59:666.3.022.82

PREVENTION OF CRACK FORMATION DURING PLASTIC MOLDING OF ARTICLES FROM HIGH-ALUMINA BODIES

S. V. Popov[1]

Translated from *Steklo i Keramika*, No. 8, pp. 22 – 24, August, 2013.

The reasons for the formation of and methods for preventing structural cracks during the formation of parts from high-alumina ceramic in augur presses are examined.

Key words: high-alumina ceramic, technical alumina, augur press, structural cracks, paste composition, press parts, moisture content of body, drying regime.

A high content of aluminum oxide in high-alumina ceramic is attained by introducing technical alumina into the body [1]. Uncalcined G-0 and G-00 γ-alumina and calcined GK α-alumina are used in ceramic production; their structural characteristics determine not only the different technical characteristics of the finished parts but also different parameters of the suspensions and bodies at the corresponding stages of the technical process [2]. For example, compared with G-00 compared with GK alumina increases the moisture content of the ceramic slip and the molding body, increases the shrinkage of parts during drying and firing, and so forth. Its main advantage is lower cost because the energy costs are lower during fabrication, so that it is widely used, specifically, in the production of milling bodies and imparts the requisite properties to them.

The method used to mill technical alumina also has a considerable effect on the technological characteristics of the body. For example, suspensions with alumina from wet milling are prone to thixotropy and coagulation structure formation and they are more stable against sedimentation than dry-milled alumina [3].

Different clays whose properties must also be taken into account at different stages of production are used as binders in high-alumina ceramic bodies. Thus, when alumina-containing bodies are processed in an augur ribbon press diverse cracks can appear on the molded parts. It is believed [4] that cracking is mainly due to stresses developing in the body during the molding process as a result of the nonuniformity of the body, structural defects, nonuniformity of the deformation of the body over the cross section of the press and other factors. In turn the formation of structural defects is explained by the orientation of the particles of the clayey component, which intensifies under the mechanical action of the augur on the body. High deformability of a ceramic body improves its structure; it can be achieved if the plasticity of the body is good, but at the same time as plasticity increases owing to an increase in the content of clay and kaolin the orientation of the clayey particles increases [5]. The ratio of the plastic and nonplastic components and the granulometric composition and vacuum compaction of the body, the shape and size of the pressed parts and other factors also affect the structural uniformity. It is noted in [5, 6] that the textural defects in the body can be largely removed in the pressing head, on whose length and coning depend the degree and uniformity of the compression of the body over the volume and, correspondingly, the restoration of uniformity of body. For this reason a great of deal attention is devoted to the construction of the pressing head, especially with a short mouthpiece. At the same time it is difficult to attain complete destructuring of the body, so that this problem must be solved from the standpoint of obtaining structural stresses not exceeding the strength of the molded parts.

The large number and sometimes the inconsistency of the factors determining the molding characteristics of bodies as well as the characteristics of the press design often make it impossible to predict with certainty the possibility of structural defects and prevent their appearance. In this case the choice of the main solution can be determined experimentally taking account of the fact that parts with a flat shape are more prone to undergo structural change than cylindrical parts [4]. This was confirmed during the molding in a K/StSV-350 vacuum press of lining tiles and milling bodies, the mix for which was prepared by the conventional porcelain slip technology (Table 1, body No. 1). Textural cracks along the end surface formed in 120 mm wide and 50 mm

[1] ITC Slavteploéko, Slavyansk, Ukraine (e-mail: natali_b-52@mail.ru).

TABLE 1. Body Composition

Body components	Component content, wt.%, in body compositions			
	No. 1*	No. 2	No. 3	No. 4
Clay (plasticity 11.0)	15.0	–	–	–
Clay (plasticity 11.8)	15.0	–	–	–
Clay (plasticity 15.0)	–	30.0	30.0	23.0
Dolomite	8.0	8.0	5.5	5.5
G-00 alumina	62.0	62.0	62.0	62.0
Barium carbonate	–	–	2.5	4.0
Pegmatite	–	–	–	5.5

* Main.

TABLE 2. Body Properties

Index	No. 1	No. 2	No. 3	No. 4
Milling fineness of the components according to No. 0063 sieve residue, %	1.5	1.0	1.0	1.0
Plasticity number of the body	7.1	7.7	8.4	8.9
Slip fluidity, sec	5.4/8.5	5.1/7.2	4.3/4.9	3.9/4.0
Number of tiles with cracks after drying, %	100.0	100.0	35.7	17.6

thick tiles even during the preliminary drying (slow drying) of the tiles, while these defects were not present in 25 mm in diameter milling bodies.

To prevent defects finer milling was performed and the composition of the body was adjusted by introducing the following components (see Table 1):

– clay with higher plasticity to increase the overall plasticity of the body, which decreases the friction between the body and the inner surfaces of the press and, correspondingly, the proneness of the body to rotate, improves the joining (intergrowth) of its individual layers during compaction and ‘suspension’ of the slip and decreases the possibility of its separation even with a lower content of clayey materials in the body;

– barium carbonate as a finely milled plasticizing additive;

– pegmatite as a nonplastic material to increase the strength of the body and the resistance to disruption of its continuity.

All these adjustments were also indirectly aimed at improving the fluidity of the slip, which increases the uniformity of the body during filter pressing and, correspondingly, during molding.

Milling bodies, annealed at 1370°C, were manufactured from these bodies in order to check the characteristics of the finished parts. All bodies corresponded to the standard specifications.

TABLE 3. Structural Changes in the Press Units

Body*	Length, mm, and shape of the pressing head	Additional elements in the press design	Number of tiles with cracks after drying at 25°C, %
No. 1	280, conical	None	100
No. 2	Same	Ring-shaped insert of length 200 mm in front of the head	100
No. 3	″	Same	40
No. 4	″	″	25
No. 4	″	Ring-shaped insert with 30 mm high counterknives	8
No. 4	″	Ring-shaped insert with 70 mm high counterknives	42
No. 1	Changed	None	0

* See Table 1 for the body compositions.

It follows from the data in Tables 1 and 2 that body No. 4 with plasticity number 8.9 has the best properties. Lower plasticity gives worse results. At the same time it is evident that if only the properties of the bodies are adjusted, it is impossible to completely prevent cracks from appearing, so that subsequently the conditions for processing the bodies in the press were adjusted.

Structurization of the body in augur presses by smoothing the velocities over the cross section of the flow and ensuring uniform deformation of the body can be prevented [6] by decreasing the rotation of the body in the press and the external friction between its working parts and the body; but, varying the rotational frequency of the augur shaft with the aid of the gear unit of the press turned out to be ineffective. This problem was partially solved by placing ring-shaped inserts with braking elements between the housing and the head, but the requisite result was obtained only with a newly developed pressing head with different shape and length giving the optimal angle of friction and compaction for long bodies (Table 3).

Thus, the new pressing head completely eliminates molding cracks even for body No. 1. All other structural changes to the press do not reach this objective.

To prevent the drying regime from affecting crack formation the tiles were dried at temperatures no higher than 25°C for 80 – 100 h to moisture content 17%, at which these defects were appeared fully manifested (see Table 3). Under production conditions the final moisture content should not exceed 0.5%, i.e., at this temperature the duration of the process must be increased significantly, which is unacceptable. A defect-free regime was chosen taking account of the effect of a change in the moisture content of the parts on their cracking during different drying periods (Table 4).

TABLE 4. Effect of the Moisture Content of Parts on Crack Formation

Period	Moisture interval, %	Moisture content rate of change, %/h	Number of tiles with cracks, %
1	27.0 – 22.5	0.61	0.0
2	27.0 – 22.5	1.14	100.0
3	27.0 – 17.0	0.22	36.1
4	27.0 – 0.0	0.56	100.0
5	22.5 – 17.0	0.12	0.0
6	22.5 – 11.4	0.61	100.0
7	17.0 – 4.8	0.61	0.0

A production regime was formulated from the data obtained for a chain, shelf, conveyer, convective dryer (Table 5) taking account of the fact that the period of decreasing moisture content in the parts from 22.5 to 17% (see Table 4) is most dangerous for crack formation.

Therefore, to minimize the probability of crack formation in parts formed in augur ribbon presses the optimization of the construction of the forming head of the press is more effective than other structural solutions and adjustments of the body composition and properties. This was completely confirmed during the fabrication of tiles from the production paste No. 1 after the installation of the new pressing head.

The data presented can be used to prevent structural cracks during the formation of parts in augur presses from any ceramic body, since as noted above the probability of the formation of this defect increases as the content of clayey materials in the bodies increases. If it is necessary to divide a bar (wadding) over the cross section into several parts, these cracks must not be allowed to form on the entire bar initially, which guarantees that there will be no cracks in the parts formed.

TABLE 5. Main Drying Process Parameters

Period	Moisture interval, %	Moisture content rate of change, %/h	Period duration, h
1	Molding – 22.5	0.61	7.5
2	22.5 – 17.0	0.12	45.8
3	17.0 – 0.5	0.61	27.1*
			Total 80.4

* Under the optimal conditions this period can be shortened.

REFERENCES

1. P. P. Budnikov, et al., *Chemical Technology of Ceramics and Refractories* [in Russian], Stroiizdat, Moscow (1972).
2. V. L. Balkevich, *Technical Ceramics* [in Russian], Stroiizdat, Moscow (1984).
3. I. S. Kainaiskii, É. V. Degtyareva, and I. G. Orlova, *Corundum Refractories and Ceramics* [in Russian], Metallurgiya (1981).
4. A. A. Krupa and V. S. Gorodov, *Chemical Technology of Ceramic Materials* [in Russian], Vyshcha shkola, Kiev (1990).
5. I. I. Moroz, *Porcelain, Faience, Majolica* [in Russian], Tekhnika, Kiev (1975).
6. N. E. Drozdov, *Mechanical Equipment for Ceramic Enterprises* [in Russian], Mashinostroenie, Moscow (1975).